Injection and Extraction for EMMA

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Injection/Extraction Challenges

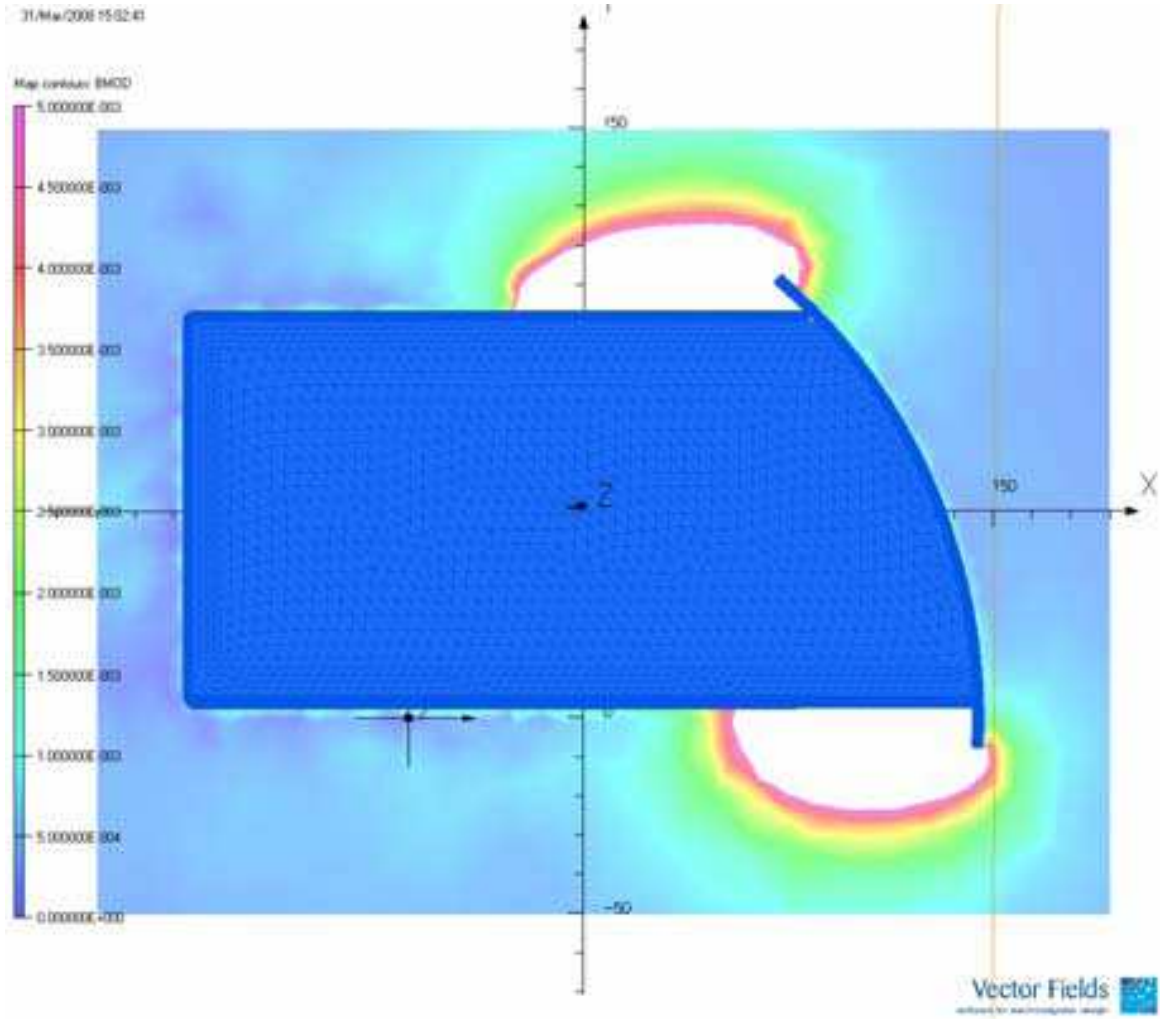
- Keeping circulating beam far from septum: stray fields
- Avoiding the beam pipe on the inside
- Avoiding the beam pipe on the outside
- Having enough kicker strength

Septum Stray Fields

- Keep error-related oscillations below 1 mm
- Fields around 1 Gauss give oscillations this size
- Even with “wings,” miss by factor of 10 at 1 cm
- Maybe not so bad
  - Not that high over entire length
  - Only that high at closest orbits
- Guess: septum $>$1 cm from circulating beam
  - Extra couple mm for septum thickness, etc.

Septum Stray Fields

White:
>5 mT



Extraction Analysis

- Launch particles on the (linearized) maximum horizontal beam ellipse
- Compute kicker strengths for each initial condition which
  - Minimizes maximum kicker strength
  - Transports beam to a given horizontal position at septum
  - Avoids beam pipe in magnets

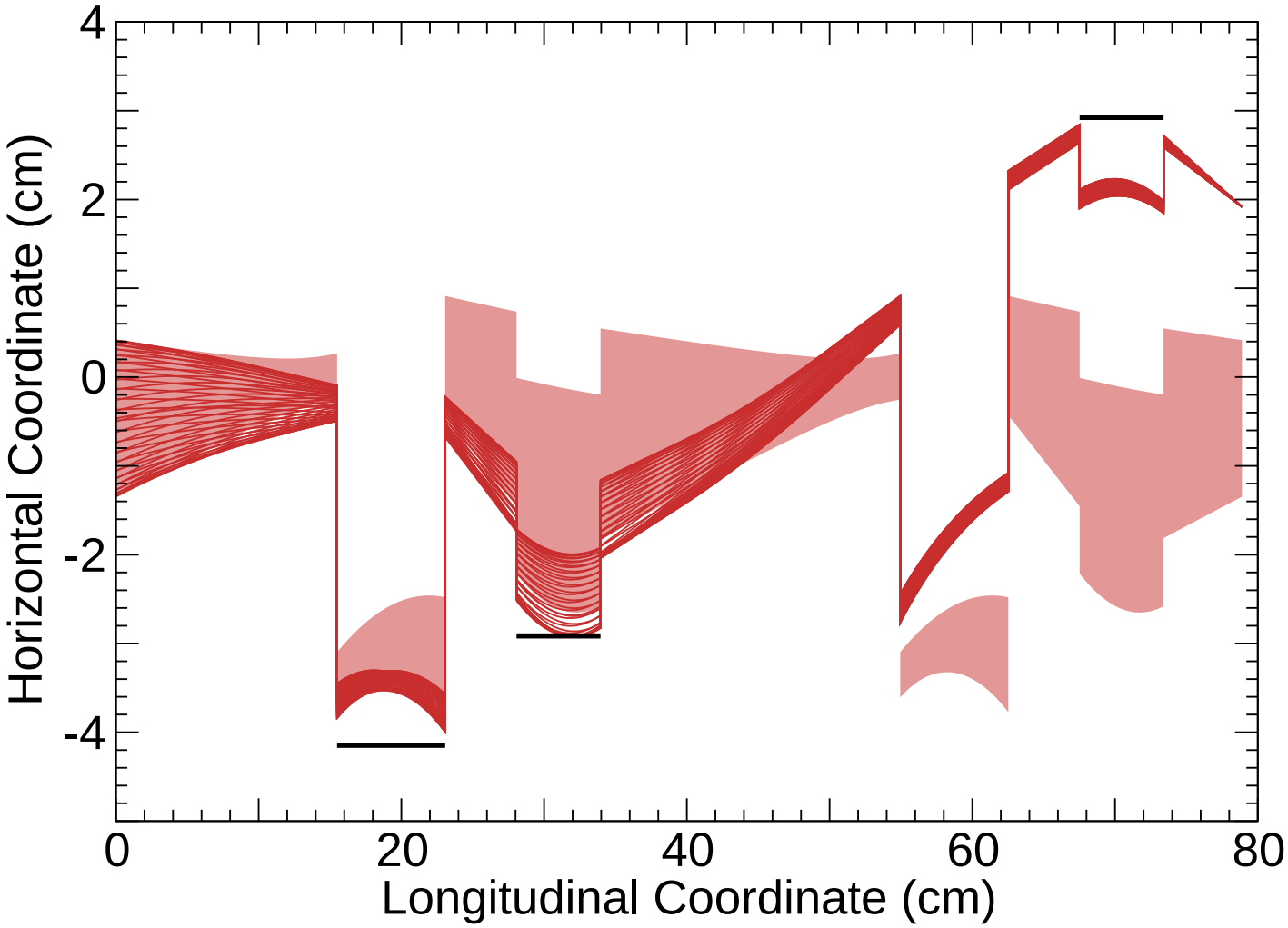
Beam Position at Septum

- Look only at septum entrance
  - Septum entrance and kicker entrance at same position in cell
- Different for each configuration and energy
- Compute maximum ellipse about closed orbit
- Find maximum position for this ellipse
- Beam position at septum is fixed distance outside this

Beam Pipe Limitations
Extraction at Low Energy

- Kickers kick in then out
- Inside of pipe at first F and D limits kick in
- Outside of pipe at second F limits kick out
- If septum too far out, no solution exists

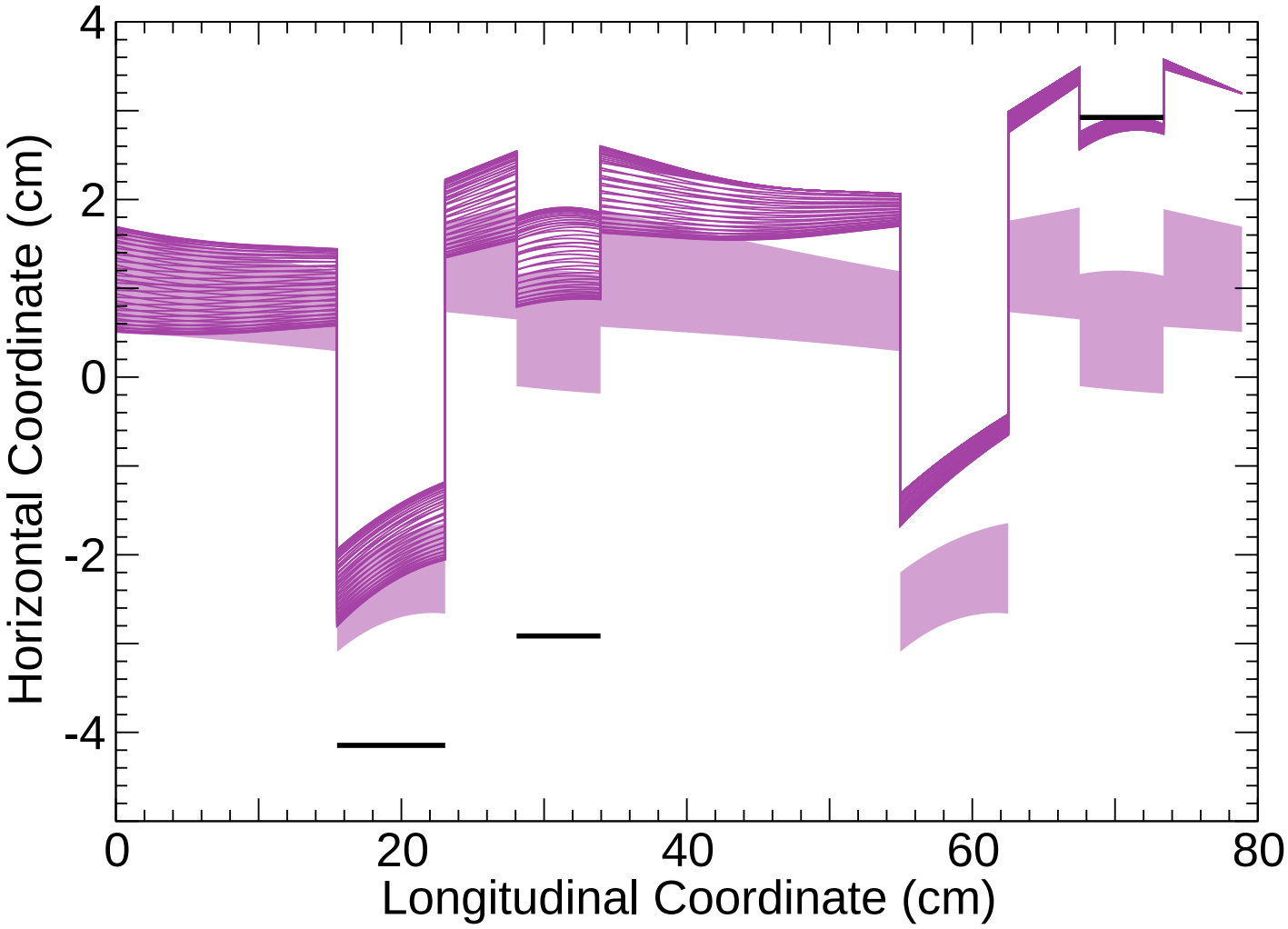
Extraction at Low Energy Baseline Configuration



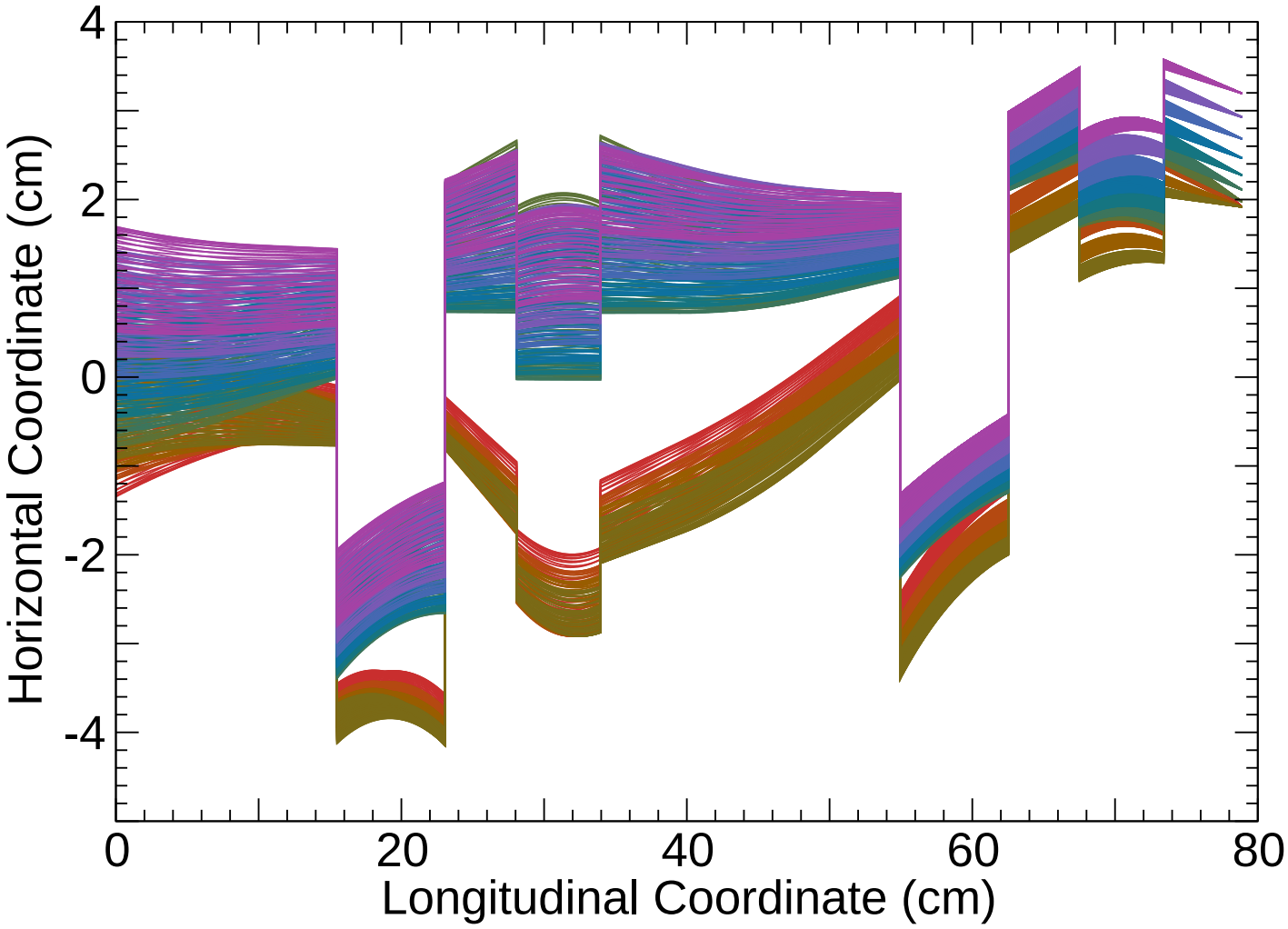
Beam Pipe Limitations Extraction at High Energy

- Ideally, both kickers kick out
- Outside of pipe at second F determines minimum angle exiting second kicker
- If septum too far out, first kicker must kick wrong way
  - Leads to large kicker values

Extraction at High Energy Baseline Configuration



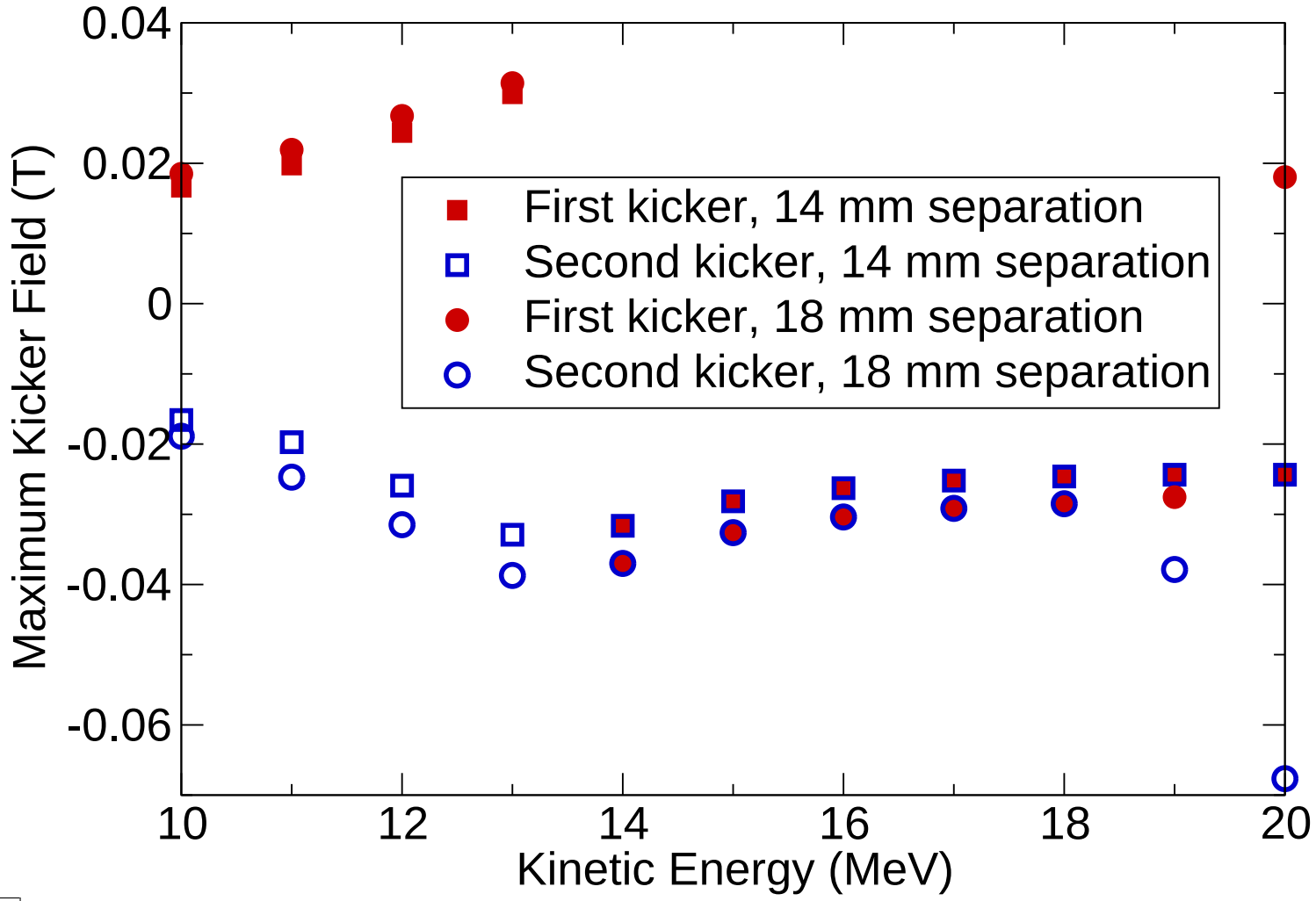
All Extraction Orbits
Baseline Configuration



Extraction Kicker Strengths

- Without aperture limitations
  - Maximum kicker strength when phase advance about $\pi/2$
    - Second kicker does all the work
  - Larger septum separation, larger kicker strength
- With aperture limitation
  - High energy kicker strengths may increase

Extraction Kicker Strengths



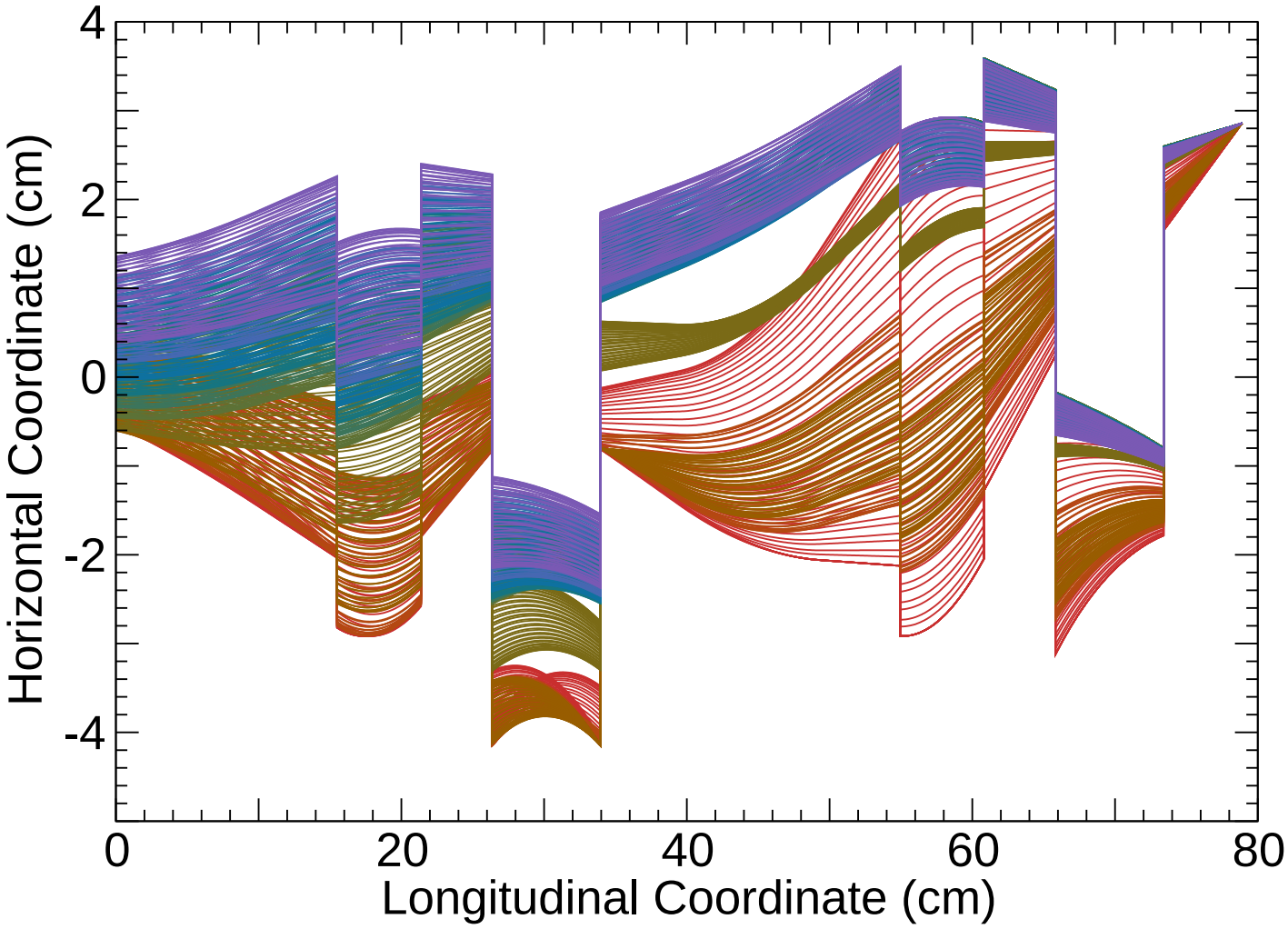
Motion Range for Septum

- Extraction septum moves with configuration and energy
- Extraction septum fixed distance outside fixed-energy beam ellipse
- 10 MeV: minimum over all configurations of ellipse maxima: -2.426 mm
- 20 MeV: maximum over all configurations of ellipse maxima: 17.711 mm
- Total travel: 20.136 mm

Injection Analysis

- Like extraction
- Extraction point outside 20 MeV orbits
  - Less travel for septum
- Magnets in best order
- Longer distance traveled
- Given septum separation, kicker strengths larger than extraction

Injection Orbits



Injection Analysis

- Maximum kicker strength when phase advance about $\pi/2$
  - Second kicker does all the work
- Some 10 MeV orbits need large kicker strength due to aperture limitation on inside
- Injection has strictest constraint on septum separation
- Only baseline configuration analyzed. . .

Better Optimization
All Amplitudes to Same Orbit

- Problems with above algorithm
  - Scanning horizontal betatron amplitude and phase requires setting 4 magnets
  - Hitting pipe aperture: mapping not linear
    - Piecewise behavior
- For given energy, all amplitudes to same orbit
  - Requires more aperture
  - But hopefully not much more
  - Avoids both problems above

Numbers for Analysis So Far

- Horizontal pipe aperture assumptions:
  - F : -21.638 to 36.753 mm
  - D : -7.416 to 84.726 mm
  - No aperture constraints in kicker
- Maximum kicker strength 0.6 T
- Extraction, all configurations, all energies: 15 mm separation at septum works
- Injection, baseline, 15 mm separation requires too much kicker strength

Neil Bliss' Best Apertures

- Neil sent drawings with largest practical apertures
  - Both magnets: -24 to +39 mm
  - Kickers: -24 to +34 mm
- These appear to be satisfactory
- Need to check painting with kicker-only

Conclusions

- Large septum separation important
- Large apertures needed
- Large kicker strengths needed
- Movable septum essential for extraction
  - Some movement needed for injection
- Kicker strength at injection limits separation
- Fixed energy and configuration, injection/extraction orbit fixed